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TECHNICAL REPORT

R10-7

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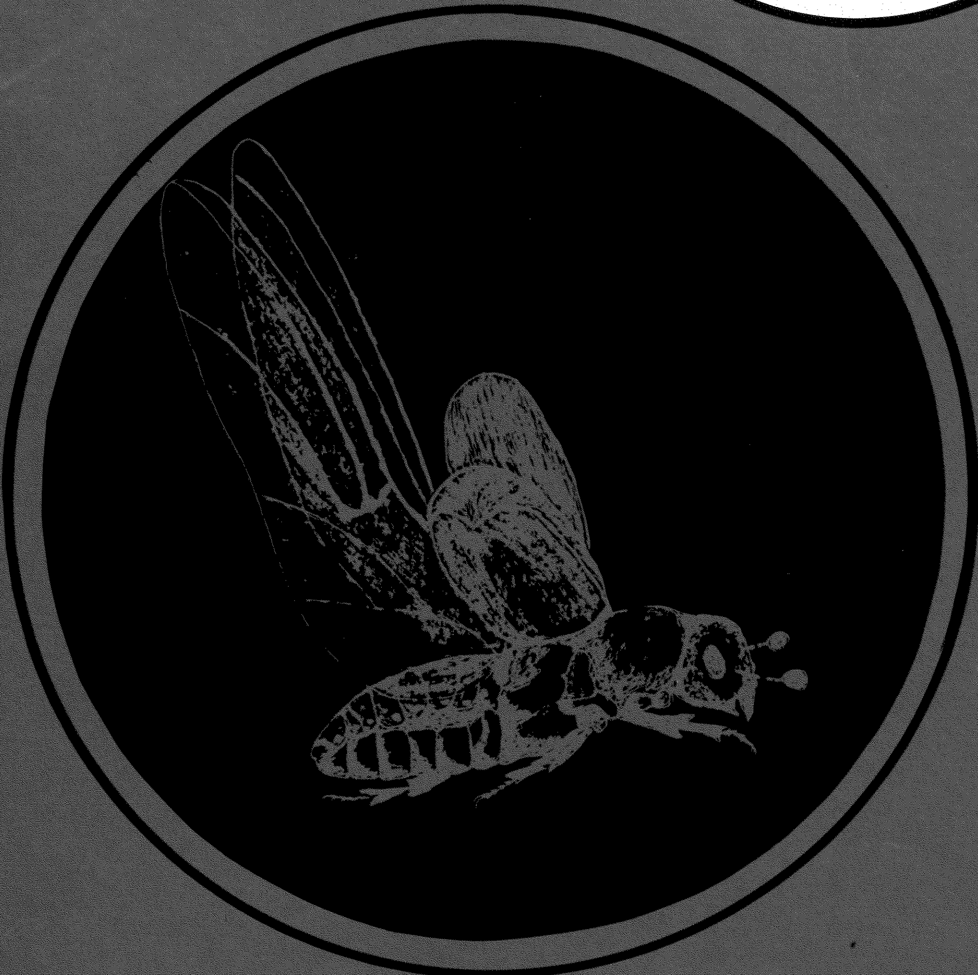

U.S. Department of Agriculture
State and Private Forestry

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EVALUATION OF MONOSODIUM METHANE ARSENATE (MSMA) FOR LETHAL TRAP TREES IN ALASKA

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ABSTRACT

The use of MSMA (monosodium methane arsenate) in spruce beetle trap trees was tested on the Chugach N.F. in south-central Alaska in 1984. Aqueous solutions of MSMA at 80 g/l (1/4-strength) and 160 g/l (1/2-strength) were applied to basal frills on standing uninfested white spruce in late May. Trees were felled two weeks later during the peak flight period of the spruce beetle. MSMA treatment efficacy in reducing spruce beetle populations in the study area was assessed in September 1984 and indicated a 99% reduction in brood for both treatments compared to untreated check trees. The 80 g/l dosage showed no repellency of attacking adults compared to untreated check trees whereas the 160 g/l dosage resulted in 33% repellency.

INTRODUCTION

The spruce beetle, Dendroctonus rufipennis, is the most destructive insect pest of Alaska's white (Picea glauca) and Sitka (P. sitchensis) spruce forests. Spruce beetle infestations covered approximately 170,316 hectares as of 1984, mostly in south-central Alaska's white spruce forests[1].

Spruce beetle control measures have included a variety of techniques such as traditional chemical control, rapid removal and utilization of infested material, burning of infested material, and the use of trap trees. Trap trees are living, large uninfested spruce which are felled as baits prior to beetle flight and can absorb up to 10 times the number of beetles as a standing tree (Wygant 1960). They can effectively attract attacking spruce beetles up to 0.4 km and less effectively up to 0.8 km. Once trap trees are infested they can either be removed, burned, peeled, or chemically treated to destroy the brood prior to the next beetle flight. Trap trees have been successfully used on a small scale for more than 30 years (Nagel et al. 1957) although recent large outbreaks of the spruce beetle in Idaho and Montana have provided the opportunity to utilize them on a larger scale. From 1981 till the present, thousands of hectares of infested spruce were treated with trap trees. A recent evaluation of these treatments indicated that trap trees, in conjunction with selective logging, effectively eliminated spruce beetle infestations (Gibson 1984). Traditional trap tree programs are usually undertaken in accessible areas as a second entry is needed to treat or remove the infested material. However, many spruce beetle infestations are located in inaccessible areas or areas where the removal or treatment of infested material is not feasible due to economic or utilization considerations.

The lethal trap tree technique is a modification of the conventional trap trees method. In practice, a silvicide is injected into the xylem tissue of living, large diameter spruce. Later, these

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[1] Data on file with Forest Pest Management, Anchorage, Ak.

trees are felled, and when attacked by spruce beetles, the subsequent brood is killed by the toxicant (Lister _et al_. 1976). The trap tree can thus be left in the woods to rot.

Injection of silvicides into the xylem tissue of trees to destroy attacking bark beetles was first demonstrated by Bedard (1938) who successfully used copper sulfate against the mountain pine beetle, _D. ponderosae_ in western white pine, _Pinus monticola_. Since then, a variety of silvicides have been tested for beetle suppression. However, two arsenic formulations, Silivisar 510[R1] and Glowon[R2], have received the majority of attention. Only Silvisar 510 is currently registered in the United States for use in lethal trap tree programs. MSMA is registered in Canada for lethal trap trees and is currently used in operational suppression programs (Hodgkinson 1983b). Appendix 1, adapted from Hodgkinson (1983a), summarizes past research on silvicide-injected trap trees for spruce beetle control.

The conventional use of trap trees has been successfully undertaken in Alaskan forests (Curtis 1982). Past trap tree studies and projects have either relied on topical application of insecticides to infested material or the timely removal of trap trees from the treatment areas. Since many spruce beetle infestations in Alaska occur in inaccessible areas, conventional trap tree methods are often not economically feasible. Accordingly, a study was undertaken to determine the efficacy of using lethal trap trees in Alaska. The results of this study are presented in the following pages.

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[1] Trade name of a solution manufactured by the Ansul Co. containing the equivalent of 680 g cacodylic acid/l (5.7 lbs/U.S. gal).

[2] Trade name of a solution manufactured by the Laters Chemical Ltd. containing the equivalent of 320 g MSMA (monosodium methane arsenate)/l (2.67 lbs/U.S. gal).

MATERIALS AND METHODS

Our original objectives were to compare the silvicides, MSMA and cacodylic acid, as to their effectiveness in reducing spruce beetle brood production in felled trap trees. However, the cacodylic acid formulation (Silvisar 510) did not arrive in time to be incorporated into the 1984 field test. Consequently, the following discussion pertains to MSMA (Glowon) only.

Study Site:

The lethal trap tree study was undertaken in a mixed white spruce-cottonwood (*Populus trichocarpa*) stand along the Sterling Highway on the Kenai Peninsula. Specifically, the study site was located to the northeast of Quartz Creek where it crosses the Sterling Highway.

MSMA Treatment:

The 1984 MSMA field test was undertaken following the procedures and formulations used in recent Canadian studies (Hodgkinson 1983a,b) as described below.

On May 16, 1984, thirty uninfested white spruce, spaced at least 10 m apart, were selected and numbered, axe-frilled, and randomly treated with various dosages of MSMA or left untreated (checks). Average diameter at frill site, dbh, and total height for the thirty trees were 45.1 cm, 35.7 cm, and 22.9 m, respectively (Table I).

The MSMA (Glowon)-water solution was applied to basal axe-frills (just cutting the sapwood around the circumference of the stem) with a polyethylene squeeze bottle. The MSMA solution was applied at the rate of 1 ml total volume/2.5 cm of tree circumference (MSMA dosages of 0.50 and 0.25 ml active ingredient (a.i.) per 2.5 cm circumference). These dosages were shown to be the most effective in reducing larval success in recent Canadian studies (Hodgkinson 1983b). Injected standing spruce were left for two weeks to allow for MSMA translocation (Buffam 1971; Hodgkinson 1983a,b).

All trees were felled on May 31.

MSMA Efficacy Sampling:

Lethal and check trap trees were sampled for brood production by a 2-person crew on August 14-15. Four 232 cm^2 (6" x 6") bark samples were cut from each of the thirty trap trees. Samples were taken in pairs on opposite sides of the tree bole below midline at: (1) 3 m from butt end, and (2) at 20 m from butt end or where the tree diameter was approximately 20 cm. The following data were recorded from each sample: (1) number of attacks (entrance holes), (2) number of galleries, (3) number of dead and living adults, (4) number of dead and living larvae, and (5) the presence or absence of secondary scolytids and woodborers.

Experimental Analysis:

Data collected were transformed, if necessary, by y = x + 0.5 to overcome variations due to zero counts which were expected to exist in the treated trees. Data were then subjected to one-way ANOV and Duncan's Multiple Comparison Test.

RESULTS AND DISCUSSION

Number of Attacks:

There were significantly more attacks on the 1/4-strength MSMA treated and check trees than the 1/2-strength MSMA treated trees (Table I). The reduction in attacks or repellency (33%) with the 1/2-strength dosage was similar to the findings of Hodgkinson (1983b) and was the main reason for eliminating its usage for operational projects in Canada. Repellency may depend in part on arsenic concentrations in the phloem (Hodgkinson 1983b).

Number of Galleries:

There were significantly fewer egg galleries in the 1/2-strength MSMA treated

Table I. Frill Diameter, DBH, and Total Height and Number of Spruce Beetle Attacks on MSMA - Treated and Untreated Trap Trees in 1984.

Treatment	$\bar{x}$ Frill Diameter (cm)	$\bar{x}$ dbh (cm)	$\bar{x}$ ht. (m)	$\bar{x}$ Spruce Beetle Entrance Holes per 232 cm^2 of Bark Surface1/
80 g/l (1/4-strength)	45.6 $\pm$5.1	35.8 $\pm$2.8	23.2 $\pm$2.5	2.2$\pm$0.6a 2/
160 g/l (1/2-strength)	44.6 $\pm$6.6	35.8 $\pm$3.6	22.4 $\pm$3.3	1.4$\pm$0.8b
Checks	45.0 $\pm$4.3	35.6 $\pm$1.8	23.0 $\pm$3.5	2.1$\pm$0.7a

1/ Based on the $\bar{x}$ data from four 232 cm^2 sample from each of 10 trees per treatment.

2/ Means within this column followed by the same letters are not significantly different at the 0.05 level (Duncan's Multiple Comparison Test).

trees than the 1/4-strength dosage and check trees (Table II). This was as expected since 1/2-strength MSMA treated trees had fewer attacks.

Number of Adults and Larvae:

There were significantly fewer parent adults in the galleries of MSMA treated vs. check trees (Table II). The percent difference between the mean total number of adults found in 1/4- and 1/2-strength treated samples (2.0 and 1.9, respectively) and those in the checks (3.6) was approximately 36%. Thus, 36% of the adults left the lethal trap trees either before or during gallery construction (App. 2, sect. 5a,b); similar to the findings of Hodgkinson (1983b). It is not known whether these adults survived and/or successfully attacked other host material. Of the adults that remained in the MSMA treated trees, from 12-16% died due to the effects of MSMA (App. 2, sect. 6a,b).

There were significantly fewer larvae in MSMA treated trees than the checks. Mean total larvae found in the samples for the 1/4-strength, 1/2-strength, and checks were 0.6, 0.10, and 32.4, respectively (Table II). This represents a 98.2% and 99.7% reduction in living larvae from 1/4-strength and 1/2-strength treated trees, respectively (Table II, App. 2, sect. 1a,b).

Secondary Scolytids:

There appeared to be no difference in the presence or absence of secondary scolytids or woodborers as related to treatment or check. However, quantitative data were not recorded. All sampled trees had woodborer larvae and secondary scolytids especially of the genera *Dryocoetes* and *Polygraphus*.

From the above results, it appears that 1/4-strength MSMA treated trees can be used effectively as lethal trap trees resulting in a 98% reduction in brood with no significant repellency to attacking adults. In other words, as many adults are attracted to 1/4-strength treated trap trees as checks, but brood production is significantly reduced. Thus, the disposal of lethal trap trees is not of concern as it is with conventional trap trees. Our results are quite similar to those obtained by Hodgkinson (1983b). The Canadian Ministry of Forests is now recommending that 1/4-strength MSMA (80 g/l a.i.) become the operational

dosage for injecting lethal trap trees for spruce beetle suppression in British Columbia (Hodgkinson 1984). Future studies in Alaska should: (1) test lower dosages of MSMA (e.g. 1/8-strength) and Silvisar 510, and (2) delineate potential hazards associated with the use of MSMA treated trees as firewood and houselogs (App. 3).

Table II. Efficacy of Two Different Dosages of MSMA on Spruce Beetle Egg Galleries, Larvae and Parent Adults, 1984.

Data Collected per 232 cm^2	Means ($\bar{x}$)[1/] per MSMA Dosage		
	80 g/l (1/4-strength)	160 g/l (1/2-strength)	Check
Egg Galleries			
A. No. of Successful	4.2 ± 1.4^{a} [2/]	3.2 ± 1.4^{b}	5.0 ± 1.1^{a}
Percent Reduction	16%	36%	--
No. of Larvae			
B. Living	0.6 ± 1.3^{a}	0.10 ± 0.3^{a}	32.4 ± 10.1^{b}
C. Dead	0	0	0.11
Total	0.6	0.10	32.5
Percent Reduction	98.2%	99.7%	--
No. of Adults			
D. Living	2.0 ± 1.9^{a}	1.9 ± 1.5^{a}	3.6 ± 1.5^{b}
F. Dead	0.5 ± 0.5	0.6 ± 0.5	0.3
Total	2.5	2.5	3.9
Percent Reduction	44%	47%	--

1/ Based on the mean ($\bar{x}$) data from 120 bark samples (four 232cm^2 samples from each of 10 trap trees per treatment).

2/ Means within rows A, B, D followed by the same letter are not significantly different at the 0.05 level (Duncan's Multiple Comparison Test).

ACKNOWLEDGEMENTS

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Appendix 1. Summary of Field Studies on Silvicide-Injected Trap Trees for Spruce Beetle Control

Author	Location	Formulation	Injection Time	No. of Trap Trees Injected	No. of Trap Trees Check	Traps Left Standing or Felled	Repellency	% Brood Mortality
Chansler and Pierce (1966)	New Mexico	Full-strength Silvisar 510 and Ansar 160	Post-Attack	15	7	Standing	N/A	87%
Buffam and Yasinski (1971)	New Mexico	Full-strength Silvisar 510	Pre-Attack	757	1	Felled	Not Proven	Not Quantified
Buffam (1971)	New Mexico	Half- and Full-strength Silvisar 510	Pre-Attack	16	12	Standing and Felled	None[1]/	90%[2]/91%
Frye and Wygant (1971)	Colorado	Full-strength Silvisar 510	Pre-Attack	10	10	Felled	None	94-95%
Dyer (1973)	British Columbia	Half-strength Silvisar 510	Pre-Attack	80	80	Standing	None	5-19%
Buffam *et al.* (1973)	Colorado Arizona	Half and Full strength Silvisar 510	Pre-Attack	180	90	Felled	None	37-71%[3]/ (Colorado) 94-98% (Arizona)
Minnemeyer (1975)	Colorado	37%, 75% and 75% (twice) Silvisar 510	Pre-Attack	46	14	Felled	None	92% 100% 100%
Dyer (1975)	British Columbia	Full-strength Silvisar 510	Post-Attack	40	40	Standing	N/A	62-68% 100%

Lister *et al.* (1976)	Colorado	10%, 25%, 50% and Full-strength Silvisar 510	Pre-Attack	40	10	Felled	Repellency in Full-strength and Half-strength	40% 70% 90% 94%
Frye *et al.* (1977)	Wyoming	10%, 25%, 50% and Full-strength Silvisar 510	Pre-Attack	80	20	Standing	N/A	10-67% 73-94% 55-99% 98-100%
Mitchell[4/] (1981)	British Columbia	Full-strength Glowon	Pre-Attack	62	10	Felled	Unclear	96%
Hodgkinson[4/] (1983a)	British Columbia	Half-strength Glowon	Pre-Attack	670	55	Felled	28%	98%
Hodgkinson[4/] (1983b)	British Columbia	1/2,3/8,1/4 strength Glowon	Pre-Attack	510	10	Felled	Repellency in 1/2- and 3/8-strength	100% 99% 99%

1/ No repellency in felled half-strength treatments compared to felled checks.

2/ Brood mortality of 90% in felled half-strength treatments compared to felled checks.

3/ Mortalities from 1/2 strength = 37% and 94%.
Mortalities from full-strength = 71% and 98%.

4/ Unpublished report.

APPENDIX 2. MSMA Efficacy Calculations (refer to Table II for $\bar{x}$ used in calculations).

1. Percent Reduction in No. of Living Larvae in Treated Samples

a) 1/4

$\bar{x}$ = 32.4 live larvae in check
$\bar{x}$ = 0.6 live larvae in treated
(0.6/32.4) x 100 = 1.85%
100 - 1.85 = 98.15% reduction

b) 1/2

$\bar{x}$ = 0.10 live larvae in treated
(0.1/32.4) x 100 = 0.31%
100 - 0.31 = 99.69% reduction

2. Percent Natural Mortality of Larvae

$\bar{x}$ = 32.4 live larvae in check
$\bar{x}$ = 0.11 dead larvae in check

Total = 32.51 larvae in check

(0.11/32.51) x 100 = 0.34% natural control

3. Percent Reduction in No. of Living Adults in Treated Samples

a) 1/4

$\bar{x}$ = 3.6 live adults in check
$\bar{x}$ = 2.0 live adults in treated
(2.0/3.6) x 100 = 55.6%
100/55.5 = 44.4% reduction

b) 1/2

$\bar{x}$ = 1.9 live adults in treated
(1.9/3.6) x 100 = 52.8%
100 - 52.8 = 47.2% reduction

4. Percent Natural Mortality of Adults

$\bar{x}$ = 3.6 live adults in check
$\bar{x}$ = 0.3 dead adults in check

Total = 3.9 adults in check
(0.3/3.6) x 100 = 8.3% natural mortality

5. Percent Reduction in Presence of Adults Caused from Treatment

a) 1/4

$\bar{x}$ = 2.5 total adults in treated
$\bar{x}$ = 3.9 total adults in check
(2.5/3.9) x 100 = 64.1%
100 - 64.1 = 35.9% reduction in presence of adults caused by 1/4 MSMA

App. 2 (cont.)

b) 1/2

$\bar{x}$ = 2.5 total adults in treated
$\bar{x}$ = 3.9 total adults in check
(2.5/3.9) x 100 = 64.1%
100 - 64.1 = 35.9% reduction in presence of adults caused by 1/2 MSMA.

6. Percent Adult Mortality From Treatment

a) 1/4

Natural Mortality = 8.3%
8.3% x 2.5 = 0.21 died naturally in treated
0.5 - 0.2 = 0.3 died from MSMA
(0.3/2.5) x 100 = 12% mortality from 1/4 MSMA of those beetles that remained in treated trees.

b) 1/2

Natural Mortality = 8.3%
8.3% x 2.5 = 0.21 died naturally in treated
0.6 - 0.2 = 0.4 died from MSMA
(0.4/2.5) x 100 = 16% mortality from 1/2 MSMA of those beetles that remained in treated trees.

Appendix 3. Environmental and Toxicity Information.

MSMA (monosodium methane arsenate) and cacodylic acid are organic arsenical compounds used generally in forestry as herbicides. Their principal use has been stem injection for pre-commercial thinning. As previously mentioned, these arsenicals have been used in the control of certain bark beetles, especially those of the Genus Dendroctonus.

In the early 1970's, Forest Service thinning crews were extensively using MSMA and cacodylic acid in pre-commercial thinning programs throughout Washington and Oregon. A number of studies were undertaken during this time to determine the behavior and impact of organic herbicides in the forest (Norris 1974, Norris et al. 1983). Much of the following information pertains to large scale use of arsenicals in thinning operations where in many cases, full strength formulations are used. This is in contrast to the use of arsenicals in lethal trap trees where few trees are treated and in many cases, treated with 1/2- or 1/4-strength dosages.

Arsenicals are rapidly translocated to the foliage of treated trees. However, some remains throughout the phloem region of the tree. Any arsenicals reaching the forest litter are quickly moved to the soil with minor amounts of precipitation. Once in contact with mineral soil, arsenicals are almost completely immobile (Norris 1974, Norris et al. 1983). Thus, there is little risk of ground water contamination. Likewise, neither cacodylic acid or MSMA seriously affect forest microbial populations, their decomposition of organic matter, or other functions important in the maintenance of soil fertility (Norris 1974). The phytotoxicity of MSMA is rapidly reduced in soil (Norris et al. 1983). In aquatic ecosystems, studies have shown that careful application of MSMA and cacodylic acid in thinning programs pose little or no threat of increased arsenical levels in these systems (Norris 1974, Norris et al. 1983).

Toxicity:

The acute oral LD_{50} (rats) for both Silvisar 510 (cacodylic acid) and Silvisar 550 and Glowon (MSMA) is 700 mg/kg. These are Environmental Protection Agency designated Class III pesticides (Moderate Toxicity).

App. 3 (cont.)

Limited data are available on toxicity to fish. The 96-hour LC_{50} ranges from 12 to more than 100 mg/l, depending on species, formulation tested, etc. (Norris et al. 1983). Significant amounts of arsenicals did not enter forest streams even though chemical thinning was conducted on both sides of the streams. The arsenical levels were at the minimum detection limit of 0.01 mg/l (Norris et al. 1983).

Arsenical compounds are fairly rapidly excreted from mammals. Residues in wildlife in treated areas were somewhat elevated for approximately 30 days, then declined markedly (Norris 1974). Thinning operations resulted in little impact on cattle grazing in chemically thinned areas. Cattle grazed in forest areas during and after operational thinning with MSMA showed no mortality despite three month's exposure to vegetation (Norris 1971). Tolerances of 0.6 mg/kg and 2.0 mg/kg arsenic have been established for MSMA and cacodylic acid in cottonseed hulls for cattle feed. Most of the arsenic residues in vegetation in Norris' study (1983) fell within these tolerances. Likewise, arsenic levels were well within tolerances set by the FDA for organs and body tissues of cattle which grazed in chemically thinned areas (Norris 1974).

Limited hare mortality was observed in a chemically thinned area (Norris 1974). This mortality was attributed to arsenic poisoning through ingestion of treated browse. However, it was determined that this poisoning was not related to thinning practices but associated with poor practices at "wash" and disposal sites.

The largest potential of arsenic hazard is to forest crews applying these silvicides using non-approved or sloppy methods of application and disposal. The use of rubber gloves vs. cotton gloves; proper monitoring of mixing, handling, and application techniques significantly reduce applicator-urine arsenic levels (Norris 1974). A urine monitoring program is recommended for any operational thinning program or large scale lethal trap tree program using MSMA or cacodylic acid. Likewise, the use of "hack and squirt" method of arsenic silvicide application results in lower human arsenic levels than the use of the injection hatchet (Norris 1974).

App. 3 (cont.)

The handling and application techniques necessary for minimizing human exposure to MSMA and/or cacodylic acid will also prevent unacceptable exposure to wildlife.

Timber staff personel of the Seward Ranger District (Chugach National Forest, R-10) have recently asked about the possibility of using arsenic treated trap trees for firewood and house logs. There is very little data concerning the hazard of using such treated material. Arsenic analyses of treated spruce logs have shown that, even though the arsenic compounds are translocated through the xylem tissue, the majority of the arsenics remain in the phloem and foliage. Highest concentrations are found near the injection site and decrease up the bole. The following Table (Table III; adapted from Hodgkinson, 1983a) compares arsenic concentrations in felled lethal trap trees using both Silvisar 510 and Glowon (MSMA).

It is believed however, that the use of treated material for firewood and/or houselogs would result in minimal hazard to the user. A recent Pacific Northwest study investigated the use of herbicide treated material as fuel for wood stoves (Norris 1984). No detectable amounts of herbicide were found in the air around the wood stove. However, the use of a treated tree as a house log may be a problem due to the degradation of treated logs by micro-organisms. Arsine gas is a by-product of this degradation and may cause a problem in a closed environ such as the inside of a cabin. However, the highest phloem arsenic concentrations are found in close proximity to the injection site; a potential house log should be cut about a meter above the frill site and the tree topped and limbed. This practice will leave most of the arsenic compounds in the field. However, such usage of treated material is not recommended until further studies clarify this situation. In practice, conventional trap trees should be utilized in accessible areas. Lethal trap trees are normally used in inaccessible areas. They are left to rot.

Table III. Comparison of Arsenic Concentrations and Spruce Beetle Attack-Repellency in Felled Lethal Trap Trees (Colorado and British Columbia)

Author	Sampling Location from Butt End in m	Silvicide Dosage	Phloem Arsenic Concentration ppm Treated	Check
Buffam *et al.* (1973)	4.6, 13.7	340g/1 Silvisar 510	26.15[1/]	0.55
Lister *et al.* (1976)	1.5, 4.6, 7.6, 10.7,13.7,16.8 19.8	170g/1 Silvisar 510	8.3[2/] ±1.1	1.1[2/] ±0.1
Hodgkinson (1983a)	20	160g/1 Glowon	24.7[3/] ±7.3	1.37[3/] ±1.1
Hodgkinson (1983b)	20	80g/1 Glowon	9.6[4/] ±4.8	? [5/]

1/ The mean ppm of arsenic based on 2 sampling locations on each of 5 trees per treatment.

2/ The mean ppm of arsenic based on 7 sampling locations on each of 6 trees per treatment.

3/ The mean ppm of arsenic based on 1 sampling location on each of 11 trees per treatment (± s.e.).

4/ The mean ppm of arsenic based on 1 sampling locations on each of 10 trees.

5/ Phloem arsenic concentrations in ppm in checks unknown in this study, but believed to be similar to the 1983a study; both studies undertaken in same location.